Visible Light Communication

Advanced Wireless Communication

Red Devils

5/15/2017

Project Title:

A Hybrid WiFi-VLC Internet Access System

Contributions of the paper:

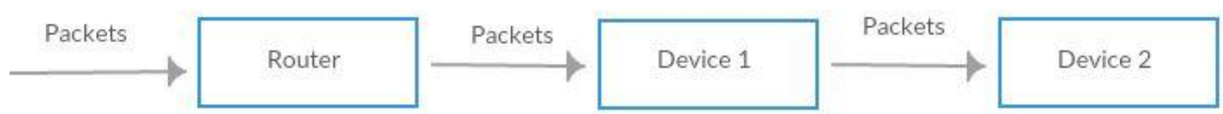
1. Design an asymmetric system comprised of WiFi uplink and VLC downlink. With that, additional bandwidth can be provided to account for the growth in network traffic. Meanwhile, the conventional RF channel is reserved for uplink data transmission.
2. Implement an integrated hybrid link enabling wireless Internet accessvia VLC downlink and WiFi uplink.
3. With typical TCP and UDP connection, to evaluate download data rate and websites loading time of our designed system and compare them with that of the traditional WiFi only scheme across various degrees of congestion.

Network Architecture:

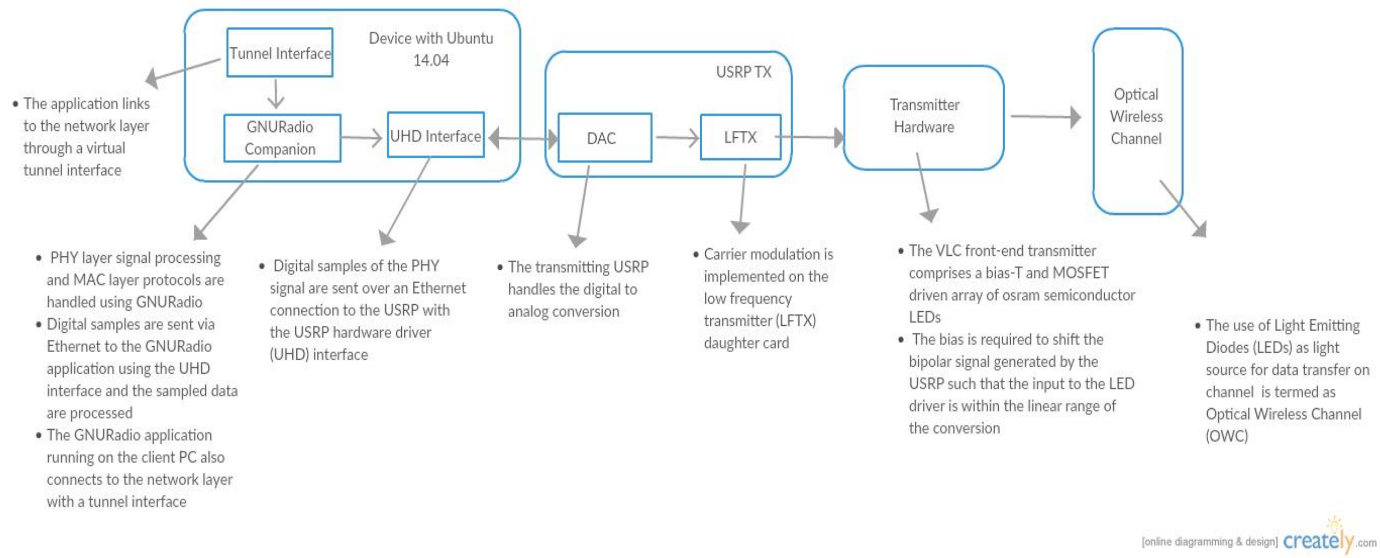
MAC and IP headers of packets flow from server and client. Server and client model are created using socket programming.

a) Uplink

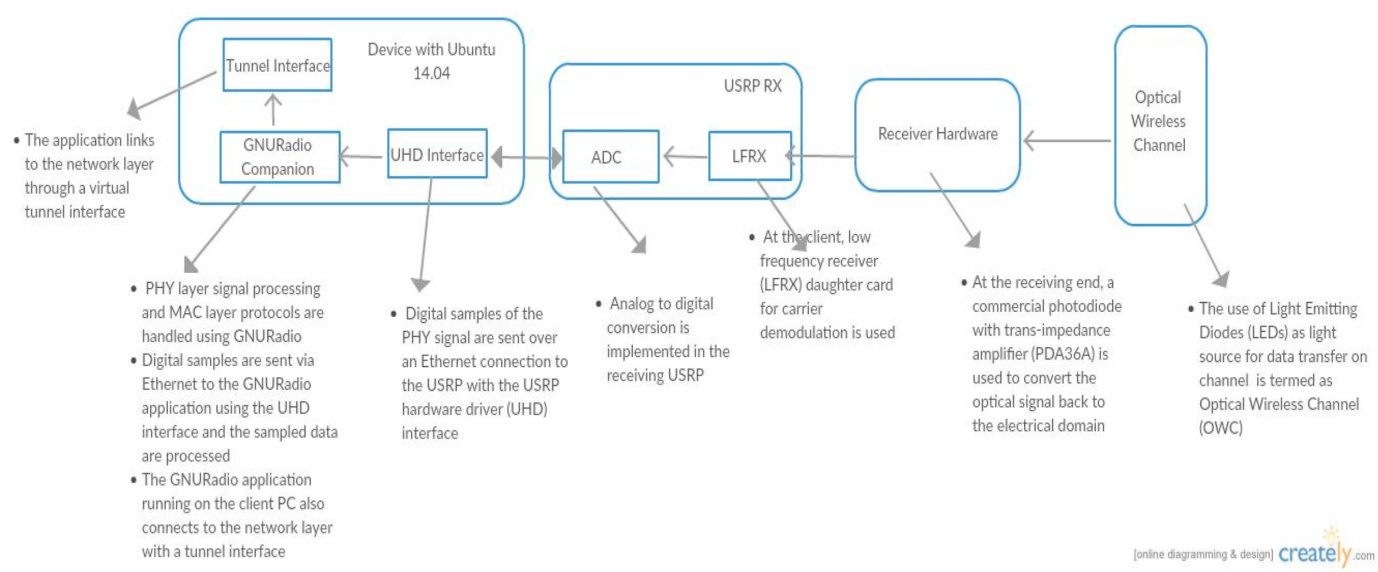
b) Downlink



Block Diagram (Transmission):



Block Diagram (Reception):



Socket Programming and OS Spoofing:

The primary challenges of an asymmetric network implementation are as follows:

1) In conventional network architecture, uplink and downlink data streams between client and server flow through the same routing path. A coordinator performing as an intermediate node is necessary in order to redirect the downlink data flow to a VLC hotspot. However, appending an additional device to traditional network framework is redundant and requires a large scale of hardware updating.

2) In our daily life, routers equipped with WiFi access point are used prevalently in many environments such as office, home and restaurants, etc. This type of router interconnects wide area network (WAN) and local area network (LAN). Mobile devices connected to the same router are distributed in the same subnet. In addition, the router's IP address is allocated to the connected hosts as a gateway. One problem occurs when redirected data packets arrive at the relaying node which acts as a VLC access point.

3) In addition to the issues mentioned above, the most challenging point lies on the client. Generally the client initiates TCP connection with the server by a three-phase handshaking procedure. First, according to the open system interconnection (OSI) model, a connection establishment request segment is generated at the application layer. Then it is encapsulated with TCP and IP headers at the network layer before being sent out through the NIC. After the request is transmitted to the server, the client starts listening to the socket with corresponding TCP port number and IP address, expecting a response from the server. Replied packets with different IP addresses or port numbers are not to be processed by the application which initiates the connection establishment. In other words, incorrect packets cannot be recognized by the application at client side.

We use Socket Programming for resolving these issues. Algorithm is yet to be developed.

Operating System Spoofing: Suppose the IP addresses of NIC B-2 is 192.168.2.100/24 and the default gateway of PC II is 192.168.1.1/24 which is the router's IP address, then we need to delete that default gateway and add a new one within the subnet 192.168.2.0/24. For example, add 192.168.2.1/24 as default gateway. After that, we add an entry in PC II's ARP table (i.e. arp -s 192.168.2.1 7

ab:ab:ab:ab:ab:ab), in order to provide the non-existent IP 192.168.2.1 with a MAC address. So far, all packets generated by application on PC II will be forced to NIC B-2. And the most significant point is that all applications (i.e. web browser) will listen to the socket with IP address of NIC B-2 and expect the response.

Current State of Project:

- Demonstration of data transfer using Visible Light.
- Empirical test bed setup and simulation framework.

Simulation Framework:

Existing work on VLC has focused on physical medium rather than focusing at network level. Whereas, future work on VLC is looking at coexistence of VLC with RF technologies.(a heterogenous network).

The base paper we are currently reading proposes an extension to network simulator which evaluates the performance of VLC/RF networks. The proposed VLC module realizes physical layer characterizing the visible spectrum mapped to various modulation schemes. Performance analysis is done of the proposed model. In the base paper, VLC downlink and WiFi uplink is considered by a combination of existing RF Simulator and the proposed VLC Simulator. SNR, BER and throughput analysis is also done.

NS3 is a discrete-event network simulator version 3 - a free software available for research and teaching purposes. ns3 is written in C++ and Python and does not support work done on ns2.

There are a lot of network simulators like ns, OPNET, OMNET, NetSim which support evaluation of large networks. But there is not network simulator to evaluate VLC. The base paper uses ns3 simulator to implement VLC Module.

There are reasons why ns3 was used in the paper - more no. of users, researchers are proliferating, ns3 is free, open source, ns3 has libraries which can be combined to evaluate technologies, ns3 supports real-time scheduler and hence used for real systems.

The new module - 'VLC-M' consists of classes and examples. The VLC module consists of channel model, mobility model, helper model, examples and scripts. Digital Modulation schemes - Variable Pulse Position Modulation (VPPM), Pulse Amplitude Modulation (PAM), and OOK (On-off Keying).

1) Node: The representation of network device (mobile or AP) and various functionalities can be added like protocol stacks, peripheral cards, etc.

2) Net-Device - Inside the node, the installation of peripheral card or NIC Card is net-device. This device allows the node to use a specific channel.

3) Channel -This represents the communication channel through which the data flows between nodes. The channels communicate between nodes via network device and the channel can be used by multiple nodes.

4) Helpers - Used to manage large networks including nodes, channels and net-devices.

5) Application - represents basic abstractions that ns can simulate. One of the applications is pcap library - packet capture

The new module is created using python create-tool. The proposed module structure consists of 6 stuctures - model, helper, examples, wscript, test, doc.

1) Model - this structure contains the source and header files for the VLC Module Classes. This includes VLC Channel, VLC mobility, VLC Propagation, Modulation schemes and SNR evaluation.

2) Helpers - This structure is to help understand complicated networks. It is mainly to understand the code in layman terms. This includes VLC-channel, VLC-netdevice helper.

3) Examples - This includes samples on how to use the code.

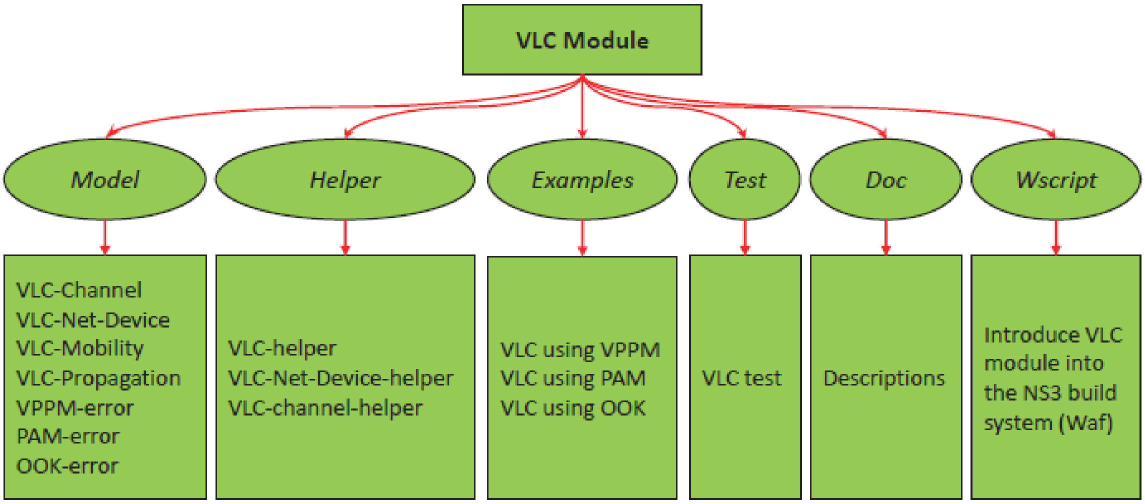
4) Test - Used to verify the module.

5) Doc - contains the descriptions on how the module works and the scope and limitation of module.

6) Wscript - used to combine the new module with the exiting ns3 build system (waf).

VLC is implemented with Intensity Modulation/Direct Detection such that the optical signal is represented by variations in the power and the received signal is converted to electrical signal. The maximum power possible constraints to C and the transmit power is say X(t). The optical intensity is non-negative so we incorporate a DC bias to the signal. Due to dual use of light, there has to be a control over illumination and the average power. In order to achieve a specific average optical power, only a certain range of source is used. Thus, we have min(X(t)) and max(X(t)) and the instantaneous optical signal power is x(t) = X(t) - min(X(t)). Average optical power - E[X(t)] and average optical signal power - E[x(t)].

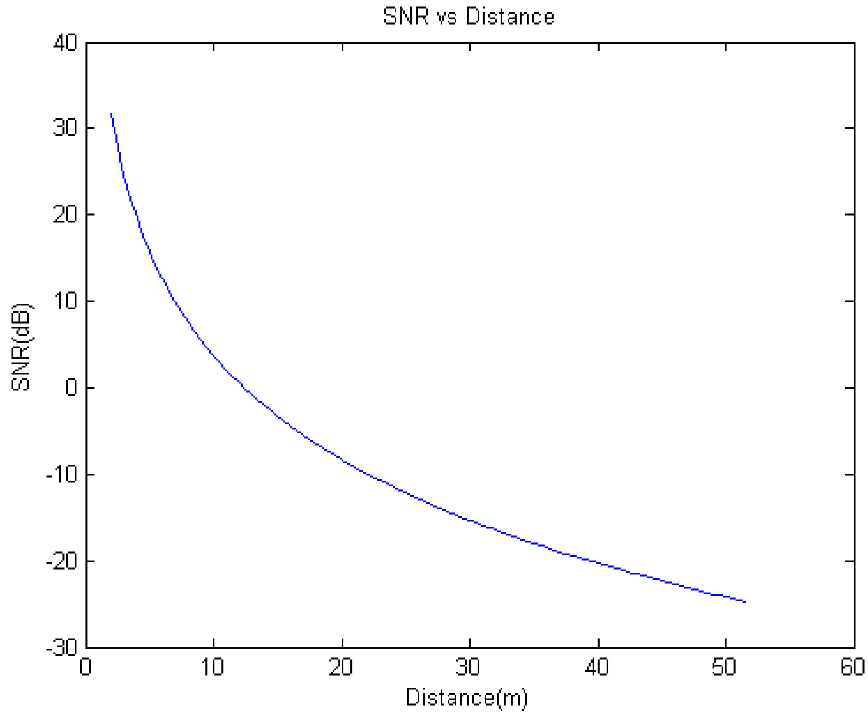
VLC Module Structure:

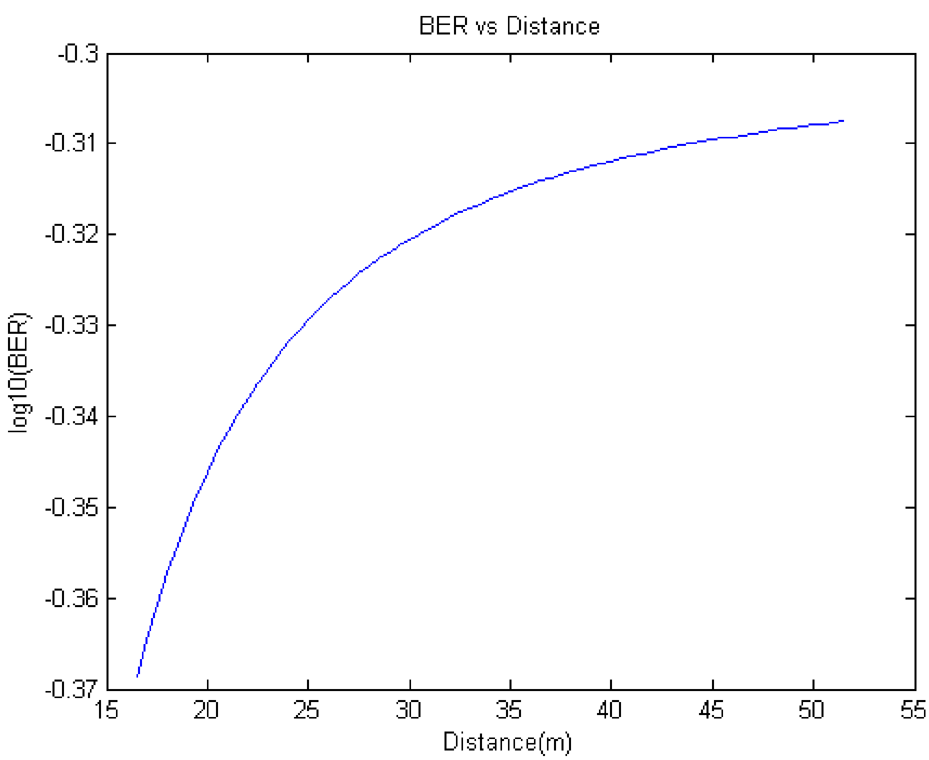


Parameters for Simulation:

Parameter	Value
Transmited Power, P_t	48.573 dbm
Lambertian Order Semiangle, $\Phi_{1/2}$	70^{o}
Filter Gain, T_s	1
Boltzmann's Constant, k	$1.3806e^{-23}$ J/K
Noise Bandwidth Factor, I_2	0.562
Background Current I_B	$5100^{-6}\ A$
Open-Loop Voltage Gain, G_{ol}	10
Fixed Capacitance Of Photo, C_{pd}	$112pF/cm^2$
Field-Effect Transistor (FET) Transconductance (gm)	30 mS
Electronic Charge, q	$1.60217e^{-19}\ C$
I_3	0.0868
PhotoDetectorArea, A	$1.0e^{-4}\ m^2$
Refractive Index, n	1.5
Field Of View, ψ_{con}	70^{o}
Transmiter coordinate	(0.0,0.0,50.0)
Transmiter Azimuth	(0.0)
Transmiter Elevation	(180.0)
Receiver Coordinate	(0.0,0.0,dist)
Receiver Azimuth	(0.0)
Receiver Elevation	(0.0)
VPPM Duty Cycle, α	0.85, 0.6
Bandwidth Factor, b	1
Distance, d	50 m
Absolute Temperature, T_k	295 K
FET channel noise factor, Γ	1.5
PAM Modulation Order, M	4
Electric Filter Bandwidth	$5e^{6}\ b/s$

Simulation Results:



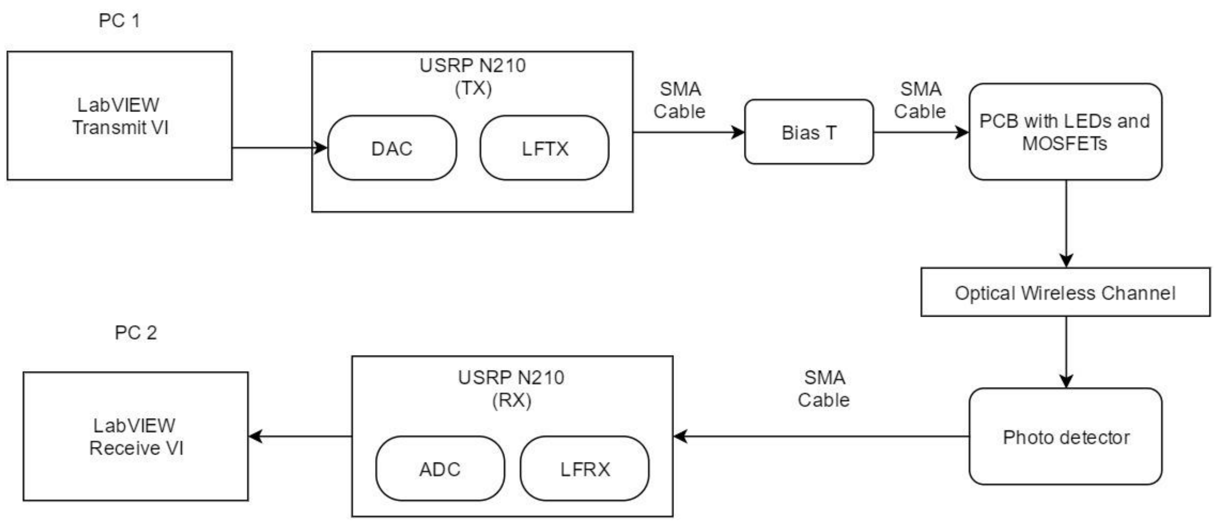


Empirical Framework:

We have experimentally shown that it is possible to transmit data using Visible Light.

- A prototype demonstrating data transmission and reception using Visible Light Communication.
- The transmitter hardware is a PCB containing LED (LUWCN5M) and MOSFETs (2n7002)
- The bias tee (ZX85-12G+) is required to shift the bipolar signal generated by the USRP such that the input to the LED driver is within the linear range of the conversion.
- The receiver hardware is a photodiode with trans-impedance amplifier (PDA36A) which is used to convert the optical signal back to the electrical domain.
- We utilize LabVIEW and USRP Hardware for empirical framework setup.

Block Diagram:



This is the set up that we created to demonstrate the data transfer using Visible Light. On the transmitter PC, there is a LabVIEW VI which decodes a sound file, modulates it using Frequency Modulation with a 1 MHz carrier frequency and transmitter gain of 10dB.

As the USRP is N210, the USRPs and PCs are connected through a local network. The USRP is connected to the bias tee using an SMA cable. The bias tee converts the bipolar signal generated by the USRP with a 2V DC bias which is provided by the voltage source such that the input to the LED driver is within the linear range of conversion. The bias tee gives output to the PCB which has ultra white colored LEDs and driver circuit containing MOSFETs.

The receiver hardware is a photo-detector with a trans-impedance amplifier circuit which converts the optical signal back to analog. On PC 2, the LabVIEW VI receives the analog signal and encodes it into a sound file which is played continuously.

Test bed Setup:

Hardware used:

USRP N210 - Transmitter and Receiver

LEDs - LUWCN5M (ultra white)

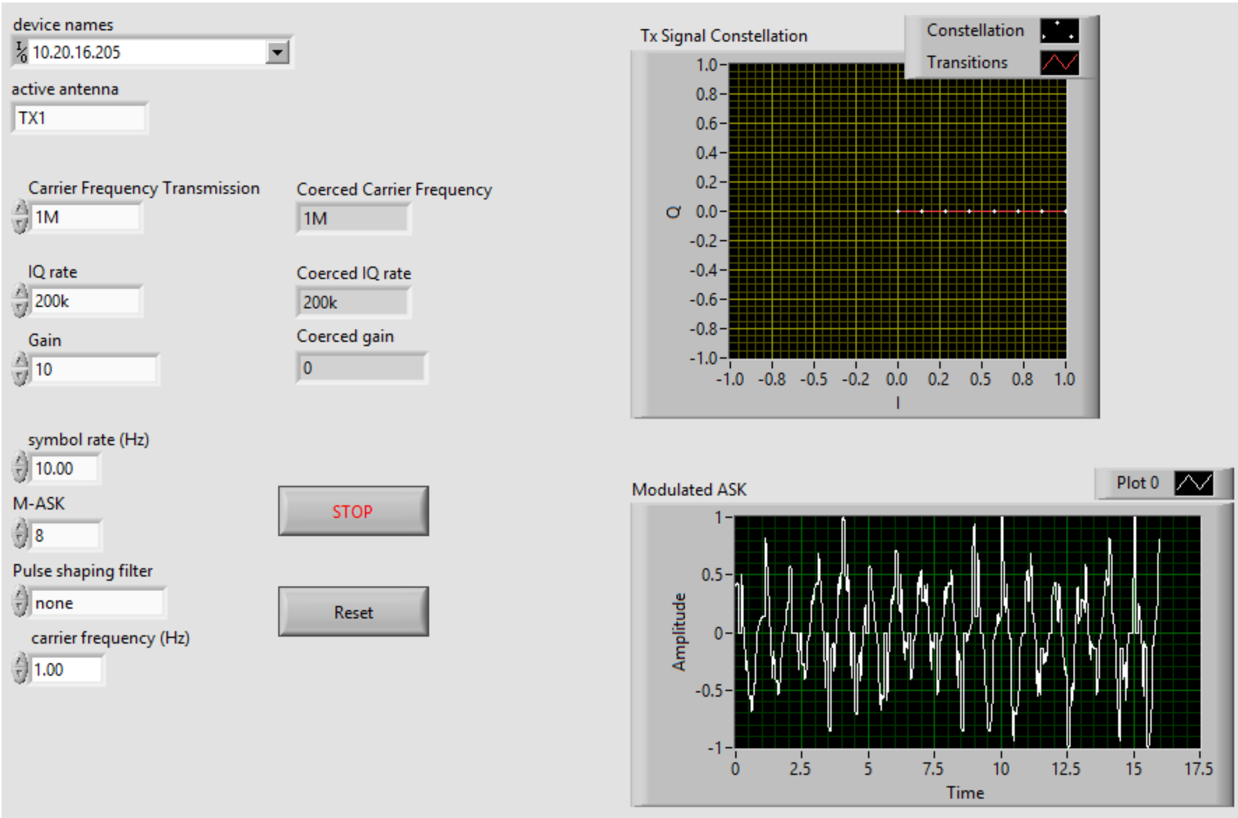
LED Drivers - MOSFETS 2n7002

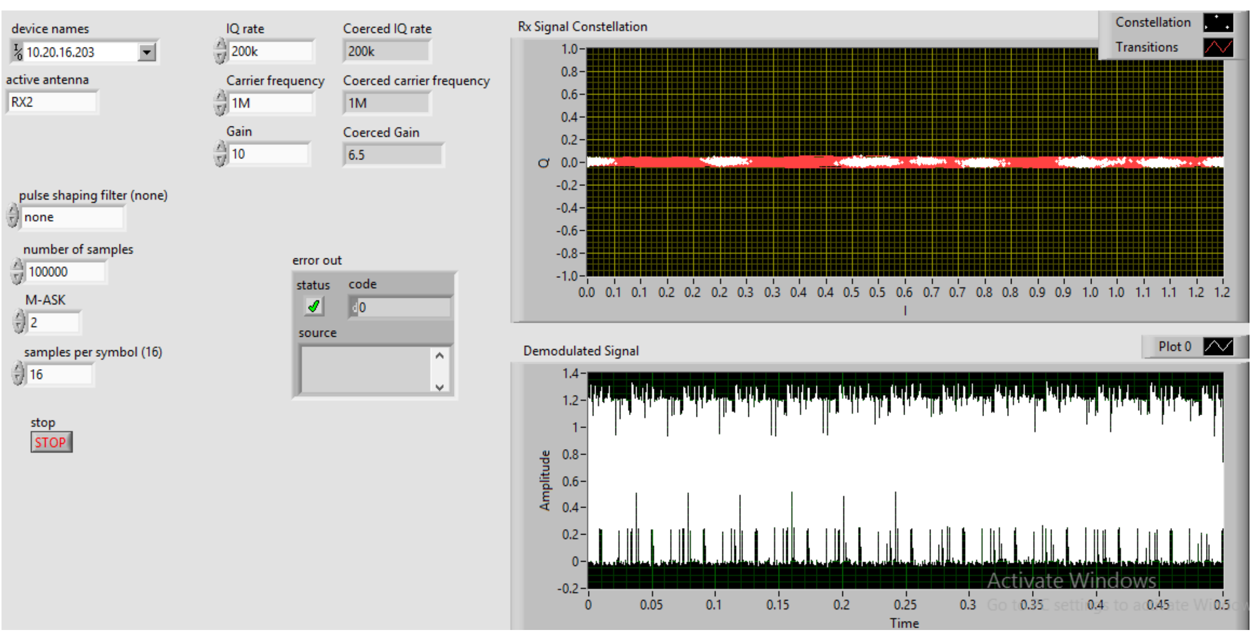
Bias T - ZX85-12G+

Photo detector - Thorlabs PDA36A

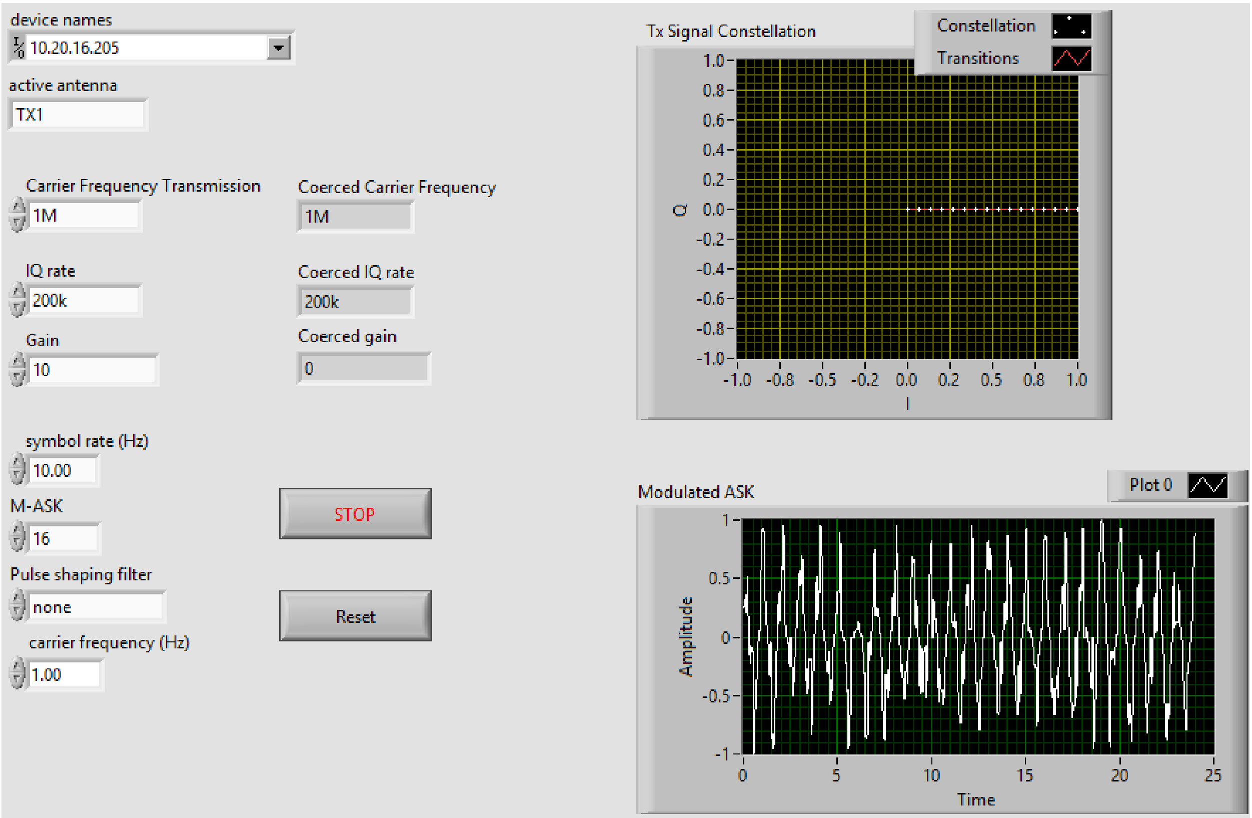
Empirical Results:

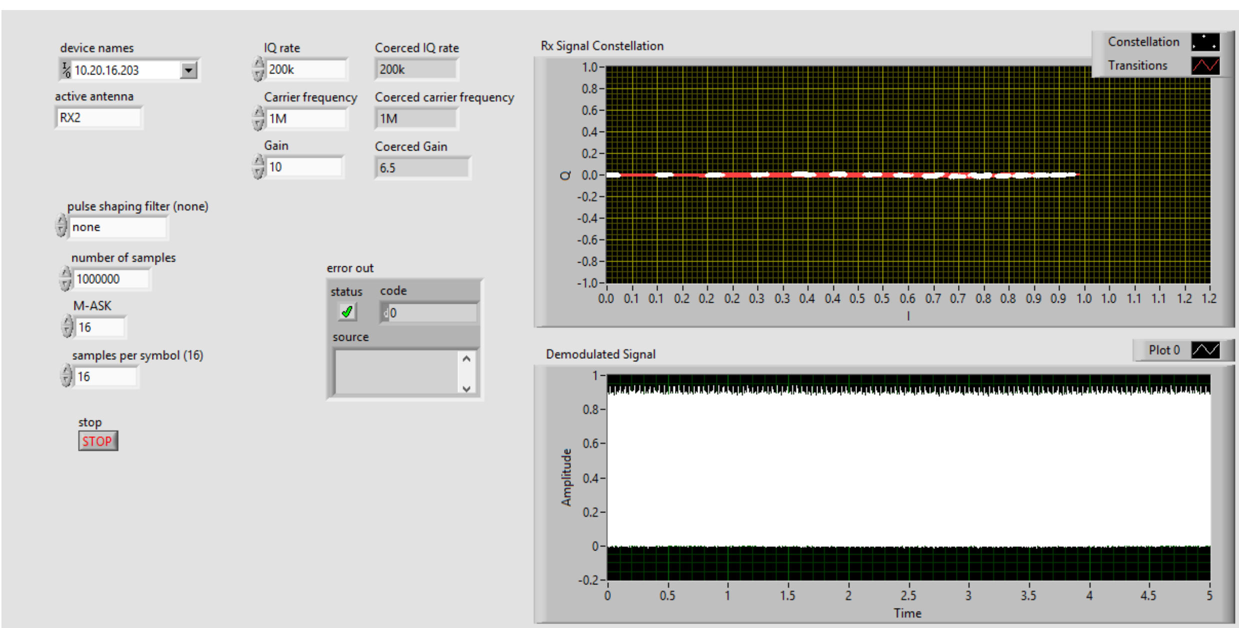
1. 8-ASK



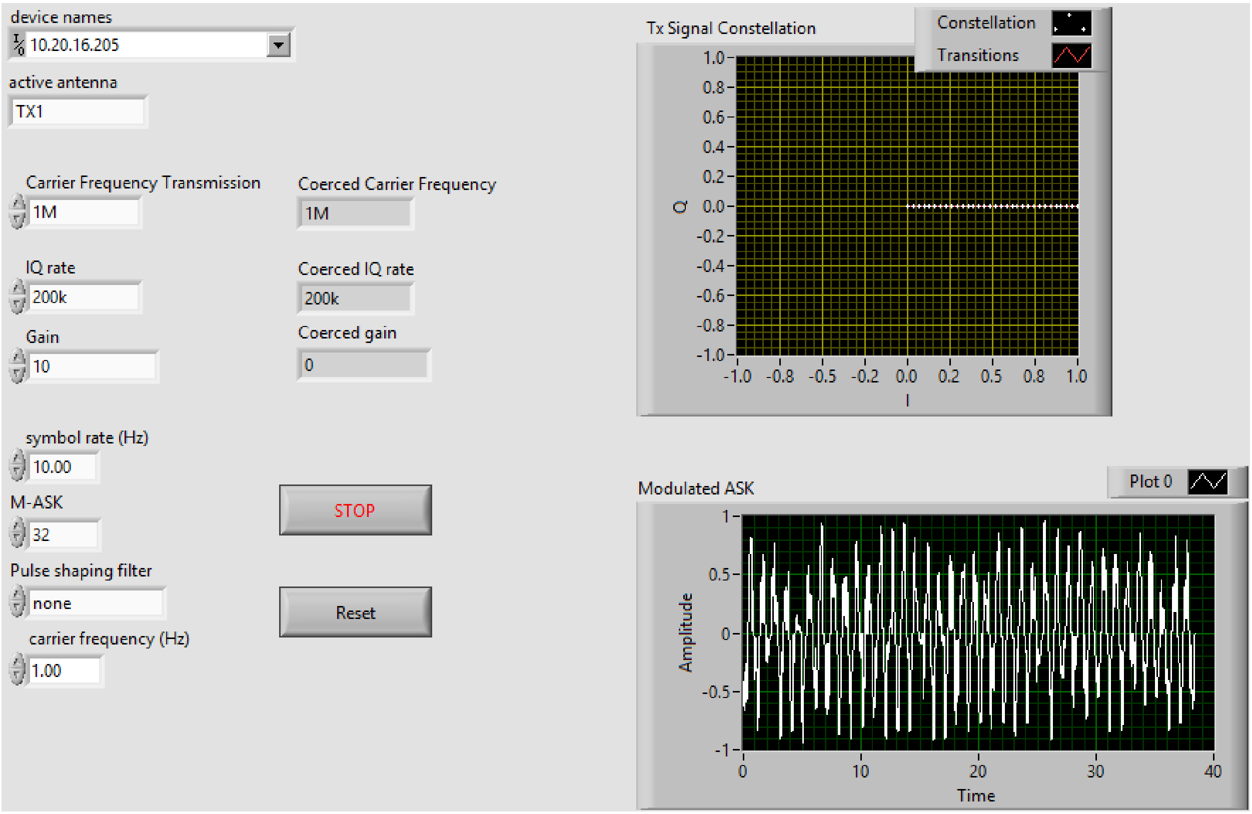


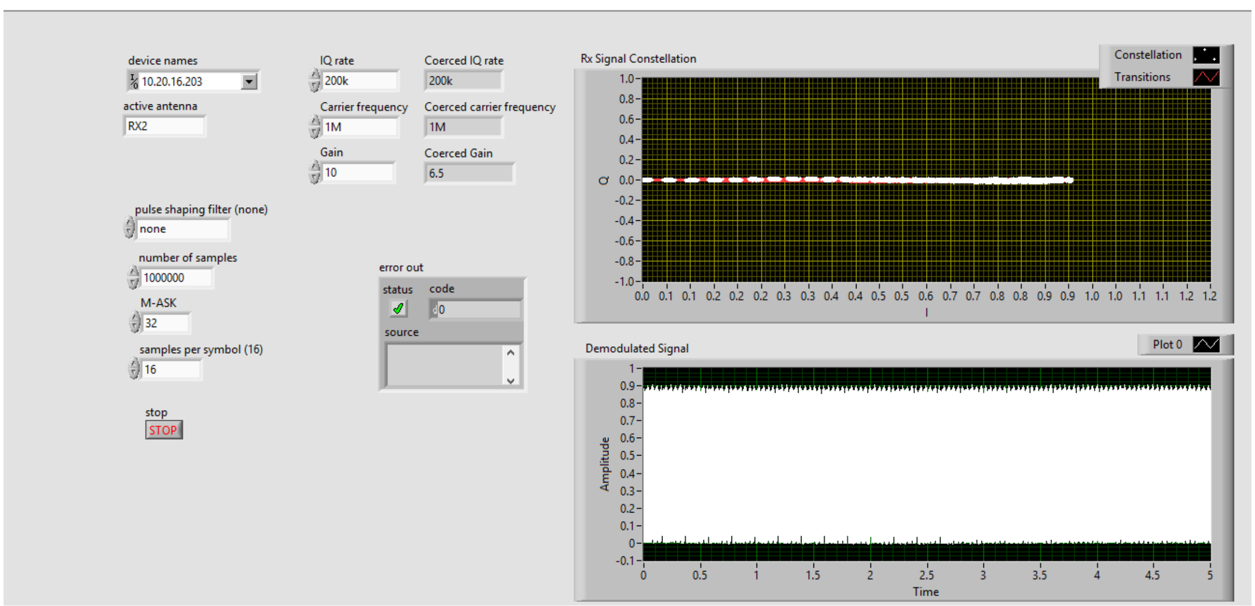
2. 16 – ASK


device names
10.20.16.205
active antenna
TX1
Carrier Frequency Transmission
1M
Coerced Carrier Frequency
1M
IQ rate
200k
Coerced IQ rate
200k
Gain
10
Coerced gain
0
symbol rate (Hz)
10.00
M-ASK
16
Pulse shaping filter
none
carrier frequency (Hz)
1.00
STOP
Reset
Tx Signal Constellation
Constellation
Transitions
Q
I
Modulated ASK
Plot 0
Amplitude
Time

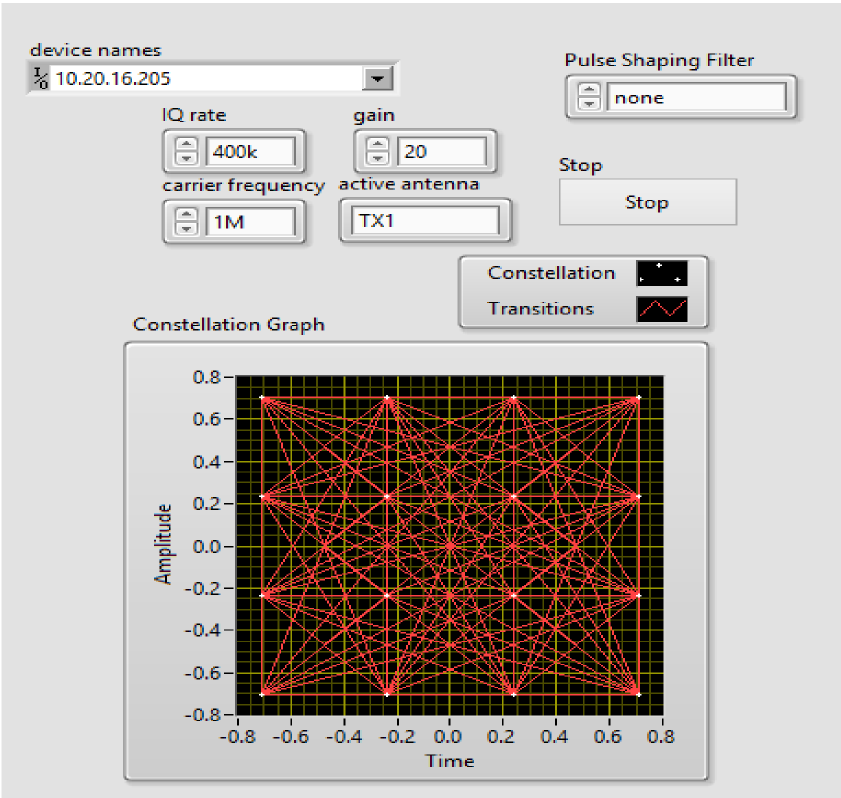

device names
10.20.16.203
active antenna
RX2
IQ rate
200k
Coerced IQ rate
200k
Carrier frequency
1M
Coerced carrier frequency
1M
Gain
10
Coerced Gain
6.5
pulse shaping filter (none)
none
number of samples
1000000
M-ASK
16
samples per symbol (16)
16
stop
STOP
error out
status
code
0
source
Rx Signal Constellation
Constellation
Transitions
Q
I
Demodulated Signal
Plot 0
Amplitude
Time

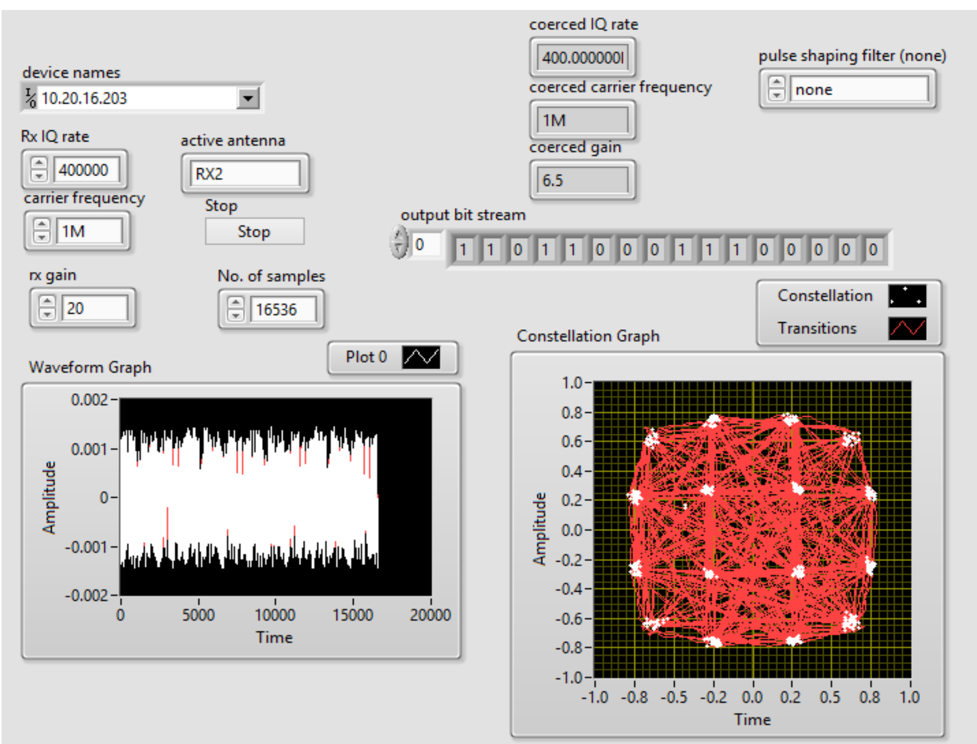
3. 32 – ASK


device names
10.20.16.205
active antenna
TX1
Carrier Frequency Transmission
1M
Coerced Carrier Frequency
1M
IQ rate
200k
Coerced IQ rate
200k
Gain
10
Coerced gain
0
symbol rate (Hz)
10.00
M-ASK
32
Pulse shaping filter
none
carrier frequency (Hz)
1.00
STOP
Reset
Tx Signal Constellation
Constellation
Transitions
Q
I
Modulated ASK
Plot 0
Amplitude
Time


device names
10.20.16.203
active antenna
RX2
IQ rate
200k
Coerced IQ rate
200k
Carrier frequency
1M
Coerced carrier frequency
1M
Gain
10
Coerced Gain
6.5
pulse shaping filter (none)
none
number of samples
1000000
M-ASK
32
samples per symbol (16)
16
stop
STOP
error out
status
code
0
source
Rx Signal Constellation
Constellation
Transitions
Q
I
Demodulated Signal
Plot 0
Amplitude
Time

4. 16 – QAM


device names
10.20.16.205
Pulse Shaping Filter
none
IQ rate
400k
gain
20
carrier frequency
1M
active antenna
TX1
Stop
Stop
Constellation
Transitions
Constellation Graph
Amplitude
Time


coerced IQ rate
400.000000
pulse shaping filter (none)
none
device names
10.20.16.203
coerced carrier frequency
1M
Rx IQ rate
400000
active antenna
RX2
coerced gain
6.5
carrier frequency
1M
Stop
Stop
output bit stream
0
1 1 0 1 1 0 0 0 1 1 1 0 0 0 0 0
rx gain
20
No. of samples
16536
Constellation
Transitions
Plot 0
Waveform Graph
Constellation Graph
Amplitude
Time

Future Work:

- Implementation with GNU Radio
- Socket Programming Implementation
- Network Infrastructure Integration